

the aid of these parasites, is that which begins at the core of over-ripe fruits of certain varieties, as, for example, the Northwestern Greening and Utter Red apples and the Clapp Favorite pear. Rots are, however, by no means confined to ripe fruits for we have the blight organism and others causing a rapid soft decay of apples and pears not yet half grown.

(3) Cracking of the fruits.—This condition not infrequently accompanies fungous spots on apples, pears, and peaches. The growth of the fruit in the vicinity of the spot is checked and as it continues in the deeper tissues a crack or split is very likely to form.

(4) Leaf spots.—These are common manifestation of fungous and bacterial diseases. A limited portion of the leaf, usually circular in outline, is killed or seriously injured and may even fall out, leaving a hole. In some cases several adjacent spots run together, forming irregular diseased areas. Often the same parasites cause a spotting of both the leaves and the fruits.

(5) Distortions.—So far as our common fruits are concerned these usually take the form of a curling, twisting, or puckering of the leaves. Peach leaf curl is an example familiar to those who have lived in peach-growing districts.

(6) Defoliation.—A few fungi, when they attack their host, cause a falling of the leaves. Sometimes in midsummer the trees may be seen almost stripped of their foliage. As the leaves are such a necessity in the nutrition of the tree, this is a very serious form of injury. It may be seen in California peach blight, peach leaf curl and to some extent in severe cases of apple scab.

(7) Galls.—While there are quite a number of examples found among different plants, the crown-gall of apple, peach, etc., and the black knot of cherry are the ones most familiar to the orchardist. The galls are caused by an abnormal multiplication of cells, brought about by the action of the organisms that produce the disease. The nodules on the roots of leguminous plants form in a similar way.

(8) Cankers.—These are dead spots in the bark, brought about by fungi or, in the case of the blight cankers of pear and apple, by bacteria. They are distinctly bark diseases, the wood being, as a rule, nearly or quite free from the parasite. There is much

misunderstanding concerning this class of orchard diseases. Often they are attributed to sun-scald, freezing, or "sour sap", while, on the other hand, the natural rough bark formation on the trunks and larger limbs of trees is sometimes mistaken for canker.

(9) Wood rots.—In contrast with the cankers, which kill the bark, we have rots that attack the wood, most often at the heart, usually leaving the bark uninjured until a very advanced stage of the disease has been reached. This class of injury is brought about principally by fungi. It is not a natural condition as some have supposed, nor is it a direct effect of water collecting in a wound. The water may favor the action of the fungi or bacteria, but it could not possibly cause the decay if no such organisms were present.

LOSSES BY FRUIT DISEASES

It would be difficult, indeed quite impossible, to give a full and accurate statement of the total damage done annually to fruits and fruit trees by plant diseases. In some parts of the United States, farmers having orchards that should be bringing in large returns make no pretense of marketing the fruit because of its diseased condition, or in the case of apples make the entire crop into cider. In other cases orchards valued at many thousands of dollars have been totally destroyed by such diseases as pear and apple blight. In the best pear-growing sections pears have proved a veritable mine of wealth until the orchards were attacked by this destructive disease. Likewise the California peach blight caused the total destruction of hundreds of acres of bearing peach trees before a remedy was found for it, and very serious injury to thousands of acres besides. The bitter rot has often caused the loss of over 90 per cent of the apple crop in an orchard, besides doing considerable damage to the twigs. Burrill and Blair* estimate that the loss in four counties of Illinois was at least \$1,500,000 for the single year of 1900. In the cooler sections of the country the apple scab makes the greater part of the crop in unsprayed orchards unmarketable. Even in Montana more than nine-tenths of the apples have been spotted in some orchards and this may be expected quite generally if scab is not kept under control by spraying. Pages

* Illinois Experiment Station, Circular 17.

might be written upon this subject, and if the total destruction throughout the country from all such diseases could be stated, it would be almost beyond belief. To bring the matter close to our own doors, there are a number of instances in which single orchards in Montana have suffered during one summer a damage greater than the entire amount expended by the Experiment Station in plant disease work for a year. Such examples could be cited almost indefinitely from all over the United States.

Two things should be strictly borne in mind in this connection. First, that more than half this loss could have been saved if all the fruit growers had followed the advice given them on good authority and, second, that were it not for the preventive measures now being carried on, the losses would be many times the present amount. For example, in many sections a few years ago almost the entire crop was being attacked by bitter rot or scab, whereas, now that the orchards are being treated, the loss does not exceed 10 per cent. Had it not been for the fall spraying devised a few years ago for the peach blight, that disease would have nearly ruined the peach industry in California by this time, and a similar treatment has brought under control the ravages of the black spot canker or apple anthracnose of Washington and Oregon. If but one-tenth of what is saved in this way could be turned over to the promotion of this line of work, many of the courses of treatment could be greatly improved.

One of the greatest mistakes is for a man or a community to hold that a particular locality by virtue of its climate is unsuited to a particular disease. We recognize that there are a very few cases where this holds good. For example, the bacterial brown rot of potatoes probably would not thrive in Montana even if introduced here and perhaps the same could be said of the apple blotch. The wheat rust has existed here for many years, but has done very little damage compared with that suffered by the states east and south of us; but a whole host of other diseases of field and orchard crops can and will become destructive here, and the few mentioned are but rare exceptions. It must be remembered that there have been those from Texas to Canada and from New York to California who have claimed this local immunity for their sections and have neg-

lected to take precautions to their sorrow. It must be conceded also, that those who are making this study a life work, who are comparing the effects of climate the world over, and investigating conditions suited to the parasites, are in a position to predict to some extent whether or not a given parasite will thrive in a given place.

NATURE OF FUNGI AND BACTERIA

Many of our most destructive diseases are caused by parasitic fungi, but the majority of the farmers and fruit growers of Montana have but a vague idea of what a fungus really is. In the first place it is a plant—although a very low form of vegetable life. Many are colorless or white, as some of our common molds; others are red like the rusts; a considerable number are brown or black, as the apple-scab fungus; and a few are blue, as the mold of oranges and lemons. Nearly all have a branching thread-like portion called the mycelium which corresponds in purpose though not in structure to the roots and stems of our flowering plants. (Fig. 1.) The threads of this mycelium may be visible to the eye as a fine mold or they may be so small as to require a powerful microscope to enable one to see them. Many fungi are not parasites, but live in humus soil, manure heaps, leaf mold, decaying wood, etc., and are called

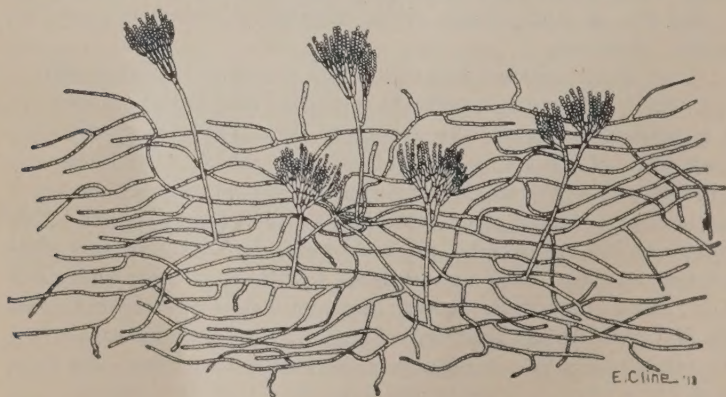


FIG. 1. Blue mold, showing mycelium below and spore-forming branches above. (Magnified about 150 times and simplified.)

saprophytes. Many parasites also, if necessary, can lead for months or even years a saprophytic life in soil, manure, etc.

In the case of most parasitic fungi, the mycelium penetrates the host plant on which it lives and injures or destroys a portion, causing the disease. Some live in the host only one year and then die out of their own accord, while others continue to live and grow in the same disease spot year after year.

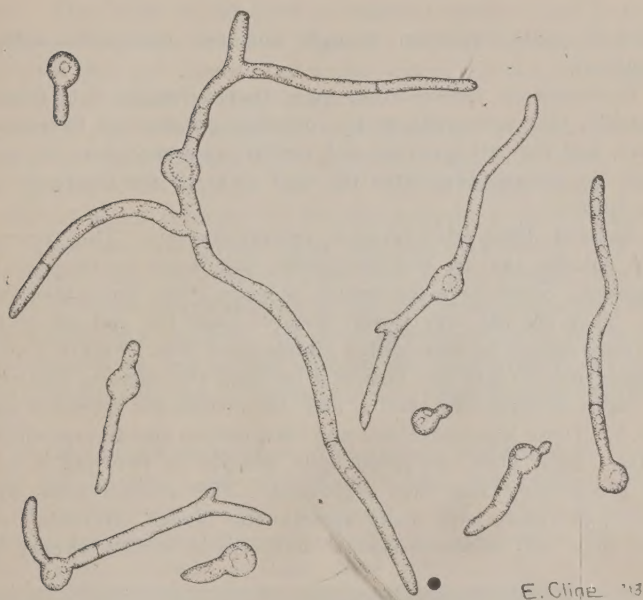
Nearly all fungi reproduce by spores, microscopic in size, which correspond in a rough way to the seeds of higher plants, but are



FIG. 2. Comparison in size between: a, fine sand; b, very fine dust; c, spores of rose rust; d, spores of wheat rust; e, spores of apple scab; f, spores of oat smut; g, spores of blue mold of fruit; h, spores of potato dry-rot fungus. (All magnified 110 times.)

simpler in structure and very much smaller. Even a strong hand lens or glass does not magnify enough to make them visible. Figure 2 shows a comparison in size between fine grains of sand, *a*, very fine dust, *b*, and various kinds of spores, *c*, *d*, *e*, *f*, *g* and *h*. They blow about in the wind like the finest and lightest dust, sometimes for miles. Fungi are very prolific in their reproduction. The number of spores formed on a single plant is usually several thousand at least, and for some species it has been computed at close to a million. Most of these, in the case of parasites especially, fail to reach the host plant and gain a foothold, but even if one in a thousand were successful the spread of the disease would be very rapid. Like seeds they require a certain amount of warmth and moisture to germinate. Without moisture they cannot grow at all, but a light dew may be sufficient. Though so tiny, each spore contains enough stored food in concentrated form to give the fungus that grows from it a good start. In germination the spore sprouts something after the manner of a seed and sends out a germ tube. (Figs. 3 and 11.) This, as it elongates and branches forms the mycelium, which is a mass of thread-like branches. The mycelium, in the case of a saprophytic fungus, penetrates the humus soil or other organic material and absorbs food for growth like the root hairs of the higher plants. It is usually so constructed and possesses such vitality that a tiny branch cut or broken off will develop an entire new plant. In the case of a parasitic fungus, the mycelium penetrates the host plant through a wound, through a tiny breathing pore, or even in some cases directly through the cell walls. Once inside the host plant it absorbs its food from the living cells at their expense and in some instances it even gives off a poisonous substance to kill them.

The treatment of fungous diseases by spraying, by fumigation and by soaking the seed in chemical solutions, depends for its success upon killing the spores before they germinate or at the time of germination. After the spore has grown out into the thread-like mycelium and this has penetrated the host plant, spraying will not, except in rare cases, kill the fungus which, protected by the host plant, will continue to develop and produce a disease spot. The spraying solution is deposited on the surface and does not



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FIG. 3. Germinating spores of the blue mold of fruit. (Magnified 730 times.)

penetrate the plant. Spraying is, therefore, a preventive of disease, not a cure. When several sprayings are called for at intervals of a few days or weeks it is because the spores continue to fall on the plants for some time and the first spray has become washed off or has lost its strength, or new leaves and shoots have grown out since the solution was applied and are, therefore, unprotected. The spores lose their vitality with time, after which they cannot be made to germinate. The time required for this to take place varies greatly with the species of fungus and with the conditions of climate, etc. Some retain their vitality for at least two or three years while others die in as many weeks. Very many serve as "summer spores" to propagate the fungus for a few months only, but cannot live over winter. In general it may be said that the greatest danger of infection is almost immediately following the

period of spore formation, though this rule has some notable exceptions.

It should be remembered, then, that a fungus is a form of plant life, that it reproduces by countless numbers of microscopic spores, and that all spraying and similar treatment must be given before the fungus penetrates the host plant or the treatment will be a failure.

Bacteria differ from fungi in several respects. They are very much smaller and are not thread-like, but round or more or less elongated. Some have the power to swim about and others have not. They are the very lowest form of plant life and are so tiny that they cannot be seen with a simple hand lens. Figure 4 shows a comparison in size and structure between the bacteria that cause the blight of apple and pear, *a*, and the microscopic spores of apple scab, *b*. There is no mycelium and there are no special reproductive bodies. Each little one-celled body pinches in two and it is by this means only that they reproduce. This process goes on so rapidly, however, with many species, that under favorable conditions they will increase several million-fold within twenty-four



FIG. 4. Comparison in size between apple-blight bacteria, *a*, and apple-scab spores, *b*. (Magnified 1700 times.)

hours. They exist on the earth in countless numbers and there are hundreds of species. Most of these are entirely harmless to mankind and some are indeed very useful, but a few cause diseases in animals, and others diseases in plants.

One of the most important considerations from our point of view is how these bacteria move about and reach their hosts. Their own powers of locomotion are very limited; they cannot propel themselves at all through the air and scarcely at all through the soil. Some can swim in the water, but only very slowly. By their own efforts they could not go from one tree to another, but with the aid of outside agencies they do succeed in moving about, often with considerable rapidity. Of these agencies flowing water is of some importance, but certain insects and man himself are much more important carriers of the bacteria that cause diseases of orchard trees.

In their attack upon plants and animals bacteria do not work singly but by their rapid multiplication form incalculable numbers and injure the host by their concerted action. Their method of attack is usually this,—that a few only gain entrance to the plant, either through wounds, as those made by tools, etc., or by insect bites, or else by swimming about in rain or dewdrops on the leaves they find the breathing pores in the epidermis and pass through into the interior. There they multiply more or less rapidly until there is almost a solid mass of them, and secrete poisonous substances that kill the living cells of the host. In many cases they secrete solvents also that dissolve the cell walls, making a soft decay, and are thus able to invade the plant farther and farther, absorbing their food from the juices of the host. There are, of course, many variations in the details of the processes that give different characteristics to different bacterial diseases. Some quite regularly invade the bark, others the wood, others the leaves, while a few attack nearly all parts.

One thing about both bacterial and fungous diseases should be well understood and kept in mind. Any one species as a rule attacks only one kind of plant or a closely related group of plants. There are comparatively few exceptions to this rule. For example, there are diseases found on the apple, but on no other fruit; there

are others found on the peach and other stone fruits, but not on core fruits; but there are very few diseases found on both the apple and the peach for these two are not quite so closely related though they belong to the same family. Diseases found on the apple or the peach and also on the cottonwood, willow, or grape are almost unknown. Crown gall is an exception.

METHODS OF COMBATING PLANT DISEASES

It is the duty of the plant pathologist to study plant diseases and make sound and practical recommendations for their control. In some cases this is an easy task, in others a more difficult one. There are two problems involved,—the prevention of diseased conditions and the restoration of health when these conditions have been allowed to occur. Under the head of prevention comes the great bulk of our work in plant pathology.

In the first place, we should attempt to produce our fruit from trees that are comparatively resistant to the more important diseases. Natural resistance of plants is of the greatest importance. For example, some varieties of apple and pear are very little affected by blight and the Northern Spy apple is seldom troubled by the woolly aphis. Unfortunately the varieties resistant to certain diseases are not always the most desirable in other respects. On the other hand, varieties especially susceptible to certain diseases are often absolutely worthless to plant where these diseases occur, no matter how desirable they are otherwise. For instance, it is absolute folly to plant the Alexander apple or the Transcendant crab-apple in most localities because of the blight. It should be noted that resistance to one disease does not imply resistance to another. The Rome Beauty apple is very resistant to blight but a little more susceptible to scab than the average, while the Alexander, just mentioned as very susceptible to blight, does not scab badly, and the Oldenburg is fairly resistant to both.

Aside from this natural resistance that is found in certain varieties, a special resistance can be given in some cases by inducing the proper degree of general vigor. While it might be expected that the more vigorous the tree, the more resistant it is to disease, it is a striking fact that blight is much more severe in apples and pears making a rapid growth, and relatively harmless to stunted trees.

Where sufficient resistance to disease cannot be obtained, as is so often the case, we must take measures to prevent the injurious agent,—fungus, insect or whatever it may be, from reaching the plants and attacking them. An immense amount of information has been published on this subject. Some have found it possible to grow fruit in remote localities, where for a time there is relative freedom from pests. Legislation has been enacted, making it possible for inspectors to prevent, in a measure, the spread of certain fungi and insect pests into new territory. Locations can sometimes be selected that are unfavorable to the development of such enemies. Apple scab, for example, is much less severe on the benches than in the damp low lands, while the opposite is true of blight. Apple blotch is severe only in warm climates and this is true to a less extent of bitter rot of apples and the brown rot of peach, plum, cherry, etc. This idea must not be given too wide application, however, and we should accept with caution the extravagant claims of interested parties, and verify them by consulting the Experiment Station or other good authority.

Where a parasitic fungus or pest has become established in a community, it may often be partially controlled by the wholesale destruction of its favorite haunts. Plowing under diseased leaves, burning blighted limbs, and destroying the nests of the tent caterpillar, are familiar examples.

During the last century we have found that there are some chemicals that in proper strengths will kill certain fungi without seriously injuring their host plants, and some knowledge of this subject as applied to insects has been in our possession for a much longer time. This discriminative action of chemicals is a most fortunate one for the farmer, and more and more he is taking advantage of it, his way being paved by the scientist. Seed is now treated before planting to protect the forthcoming crop. Insects are killed on nursery stock and in greenhouses by fumigating with hydrocyanic-acid gas, tobacco smoke, etc. Fungus spores are likewise killed by sulphur fumes and formaldehyde gas. Orchard trees are sprayed with arsenicals and other stomach poisons to kill chewing insects, with tobacco decoctions, soap and other contact poisons to kill sucking insects, and with compounds of copper, sulphur, etc.,

to destroy the attacking spores of parasitic fungi. Spraying has in many sections become a fine art, special nozzles and other devices being used for the different insects and fungi. Scientists have worked out to a nicety in many cases the exact time of application for the spray to give the best possible results. In other cases we have determined this only approximately or not at all.

With most fungous diseases and some insects, as the codling moth, the spraying must be done before any symptoms of injury appear. With diseases that appear every season with considerable regularity, as the apple scab, this makes little difference, as the wise orchardist always sprays; but in the case of other diseases, as, for example, the late blight of potatoes which may or may not appear during a given season, depending largely upon weather conditions, the farmer may spray when it is unnecessary, or he may decide not to spray and lose his crop. Under such conditions the problem is one of chance and should be figured out by the probabilities in that particular locality; combining, of course, the likelihood of attack with a comparison of the cost of spraying and the loss to be suffered if the disease should appear. The losses by taking a chance are in actual practice much greater than by spraying unnecessarily.

Some diseases, as wood rots or heart rots that destroy the interior of the tree, gain entrance through wounds. In the care of orchards it is always necessary to do considerable pruning and many wounds are thus made. Others are from the careless use of farm machinery and still others from the breaking of limbs by excessive loads of fruit and high winds. Wounds of this last kind are particularly bad and should be prevented by taking the necessary precautions of supporting the branches and thinning the fruit. Thousands of trees have rotted out at the heart because of this neglect. All wounds more than an inch in diameter should be painted promptly. Grafting wax is often recommended but paint is just as good and more easily applied.

While much may be said on the subject of prevention, there is little we can advise as to cure when once the attack has been made. In general we may say that if the injurious agent is removed, whether it be fungus, insect, injurious chemical, or weather conditions, the plant shows a strong tendency to recover by its own

efforts unless the injury has gone too far. When the disease is in the leaves only, a tree may recover as the foliage is shed, but if the shedding is premature, as in the case of the peach leaf curl, so that other leaves are forced from the buds late in the season, the condition of the tree may be weakened. Diseases of the fruit may likewise be of small importance to the tree itself. If the branches are affected, we may resort to surgery and cut off the injured members as in the case of blight. In some cankers of the bark, the fungus runs its course in a single season and dies out in that spot without special treatment but this will not apply to all kinds of canker.

A process that might be regarded either as a cure or a prevention is that of filling up the decayed cavities in the trunks of shade trees, etc., with clay, cement, or other materials. In one sense it is a cure and in another sense it is a prevention of further decay.

While man and the higher animals often respond to the action of drugs taken internally for the relief of bodily ailments, plants seem not to do so. Many attempts have been made to cure them of fungous and bacterial diseases by applying chemicals to the roots but without success, though extravagant claims are made by the promoters of these "remedies." Pear and apple blight especially has been the subject of this kind of experimentation. There have been numerous "blight cures" based on the application of poisonous chemicals either through the roots or through holes bored in the trunks, but none of these, so far as we know, are beneficial, and some are distinctly injurious to the tree.

There is one example of an immediately beneficial effect from the application of chemicals. When fruit trees in rather poor condition are sprayed with Bordeaux mixture, lime-sulphur solution, or even in some cases with arsenical compounds, they may show a distinctly increased vigor. The foliage becomes more dense and of a darker green color and the growth is more rapid, even if there was no specific disease or pest visible. In some cases this invigorating effect alone will pay the cost of spraying. Whether this is due to a direct tonic action of the chemicals or to the suppression of diseases that have not been recognized, we cannot say with cer-

tainty.

Lastly, we may mention that the possibilities of cure in plant pathology have not been tested so thoroughly as in animal and human pathology. This is partly because the value of single individuals in plants is relatively low, and the number necessary to treat correspondingly high. What, for example, would be the value of a sure cure for wheat rust if each plant had to be doctored individually?

SOME IMPORTANT FUNGICIDES

Fungicides in the generally accepted sense are chemical substances used to destroy or prevent the growth of fungi. A great many chemicals have this power, but to be of practical value in preventing plant diseases they must be effective in a dilution that will not seriously injure the host plant and that will not be too expensive. They have a more permanent effect also when used as sprays if they are adhesive and not easily washed off by rains.

Fungicides are applied in several ways,—in gaseous form for fumigation, and in liquid form for dipping and for spraying. In orchard work spraying is the only method of application that needs consideration here.

To spray successfully we need to know specifically what diseases we are to combat and just when the infection of the trees takes place. If the infection period extends through several weeks or months, it will be necessary to spray repeatedly, partly because the fungicides are washed off by rains and partly because new leaves appear which have to be protected, and fruits expand by growth, leaving open cracks in the coating through which infection may take place.

The fungicides most used for orchard work in Montana are lime-sulphur and Bordeaux mixture. A full discussion of the preparation and use of the different fungicides and insecticides is given in circular 36 of this station.

SOME SPECIFIC DISEASES

In preparing this section we are fortunately able in this State to limit the discussion to a few diseases, which can, therefore, be treated rather fully. As yet the orchard diseases here are few compared with the number in other states, and every effort should

be made to avoid the introduction of new ones. If the reader does not find in the following pages a discussion of some disease he may have in mind, it is because it has not yet become of importance here. Exception to this rule is made in the case of three or four that are practically new to science and that are under investigation by us, but are not yet fully understood.

APPLE BLIGHT

As this disease has already been described in a recent circular from this station and as a considerable proportion of our orchardists have become quite familiar with it as it operates under their local conditions, we will give only a condensed discussion of it here, taking up especially those points that we know need emphasis at this time.

While blight is comparatively new in Montana, it is not new to the United States. In 1794 there was published in the Proceedings of the Massachusetts Society for the Promotion of Agriculture an account of observations made upon it in the Hudson River highlands in 1780. It was there observed to be doing damage to apples, pears, and quinces, but no one dreamed of the awful ravages that would take place in later years in all parts of the country. In 1878 Doctor Burrill of the University of Illinois discovered the cause, and we may add that this was the first proof ever offered of a bacterial disease of any plant, with the possible exception of one on the hyacinth described by Doctor Wakker, a Dutch botanist, at almost exactly the same time. Bacterial diseases of animals and mankind, it may be noted, had been described several years before.

Geographical distribution.—Blight is distinctly American in origin, not being found in the native haunts of the apple and pear in Europe and Asia, though it will doubtless flourish there when introduced. From New York state it spread west and south, sometimes by great bounds over hundreds of miles on nursery stock, sometimes more slowly, through the activity of insects and other agencies. At present there are very few apple- or pear-growing sections in the United States where it has not found its way. In Montana it has been found in every important fruit growing section.

Cause.—That blight is caused by a bacterial organism* is estab-

* *Bacillus amylovorus* (Burrill) De Toni.

lished beyond all doubt: indeed the proof was conclusive more than a quarter of a century ago to all who could and would sift the evidence. Though water, soil, extremes of weather, etc., have been accused of causing blight, by those with limited experience, we know that these agencies failed to produce it until the blight was introduced and that the blight bacillus will cause it in very susceptible varieties under almost any conditions in which the tree can survive and produce fruit.

Symptoms.—The organisms usually gain entrance through the flowers, tender shoots, or wounds, which may perhaps be very tiny. The bacteria multiply very rapidly under favorable conditions and invade the bark, leaves, or fruit, but not the wood except close to the cambium. The injury to the bark is the most serious. The disease spreads continuously in all directions, but most rapidly downward as a rule, in the direction in which the manufactured food from the leaves is passing.

The bark is eventually killed where attacked and the inner layers turn pinkish in color and become sticky to the touch. Later it turns dark and dry and shrivels somewhat. When conditions are favorable the disease may invade new bark at the rate of several inches per day. It has even been known to run from the top of a bearing tree to the roots in a single season. While this rapid spread is going on the discoloration of the bark does not keep pace, and as a result one cannot be sure how far the germs have gone. It is a mistake, however, to suppose that they circulate through the tree in the sap and break out in spots here and there. When such spots occur they are the results of separate infections. The progress of the disease through the bark from any point of infection is continuous.

The leaves when attacked first wilt, then quickly turn a reddish brown, not black as in the pear, and often remain clinging to the tree after the others have fallen.

The flowers when infected by bees or other insects take the disease readily, but if conditions are unfavorable they drop their petals normally and it may be weeks before a wilting of the cluster and a failure of the fruits to develop give evidence of what has happened. In very hot weather, however, the petals may turn



FIG. 5. Large apple limb with two hold-over blight cankers. One started in the grafts and the other in the spur at x.

brown and shrivel on the tree.

Fruit infections are not common on most varieties, but in the Alexander they may usually be found in considerable numbers. They are characterized by large water-soaked spots that soften rapidly, but do not turn dark so quickly as some other fruit rots.

From the infected bark, leaves, and fruits a sticky exudate is usually forced out, either in tiny droplets or so abundantly as to run down in a streak. This is at first whitish or nearly transparent in color but quickly turns yellow or brown. It contains enormous numbers of the bacteria. When it is forced out slowly, it dries down to some extent and may not be very conspicuous, but if a

fresh specimen is cut, the end put in a glass of water and the whole sealed up in a tight jar or chamber, a surprising amount can be collected. This gummy exudate is one of the most characteristic symptoms of blight.

Host plants.—Blight is found most commonly on the apple, pear, and quince. It has been known to attack the apricot and plum, and in one orchard in the Bitter Root Valley the sweet cherry, but these fruits nearly always escape even when growing among badly blighted apples and pears. It has been found also on the service berry, hawthorne, and mountain ash, but it attacks these shrubs so seldom and dies out in their bark so readily that it is doubtful if it spreads from them to cultivated trees except very rarely. It does not attack the poplar, willow, alder, dogwood, or buffalo berry, as some of our orchardists have reported. All such reports that we know of are based on mistaking fungous diseases of these shrubs for the bacterial blight, which is totally different though it shows external symptoms that are similar. There is no doubt that the presence of blight on native shrubbery is of no practical importance in blight control in Montana.

Damage.—Blight is one of the most destructive of all diseases of the apple. While some varieties suffer very little from it, others

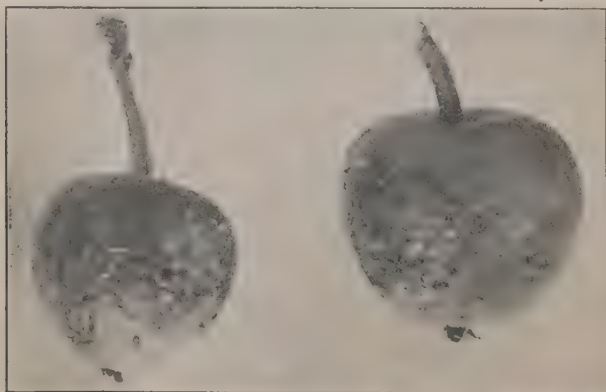


FIG. 6. Blighted Alexander apple, showing strings and droplets of bacterial exudate.

cannot be grown with commercial success where blight exists. There are cases on record where orchard blocks of as high as 10,000 trees have been entirely destroyed. The total number lost in the United States reaches hundreds of thousands annually. In this State thousands have been removed each year since the disease became serious. The percentage with us has been high partly on account of mistakes made in planting susceptible varieties, but these are rapidly disappearing. Besides the thousands of trees that are killed or made worthless by blight, others are badly injured and deformed by the killing of large limbs, and much money is spent in keeping the disease under partial control and preventing greater ravages.

Conditions affecting blight.—One of the most striking things about this disease is its very different behavior under different conditions. This has led to an apparent disagreement of observation and a real disagreement of opinion, especially among those who have seen it in only one locality. Of the conditions that affect the severity of blight we have two kinds,—those that influence the number of cases and those that influence the severity of the cases.

Under the former should be listed factors responsible for the spread.

(1.) "Hold over" cases.—The work of Mr. M. B. Waite and others has demonstrated that all or nearly all the new cases that appear each spring come from old ones where the organisms have survived the winter in that part of the bark where the diseased part joins the healthy. Some of these "hold-overs" may be found in the orchard, where they are responsible for a local spread, and others occur on nursery stock and may carry the disease for hundreds of miles.

(2.) Insects that accidentally take the disease germs from one case and start new ones. Of these, the honey bee, ants, green aphid, bark-boring beetles, and pear thrips, have been accused by good authorities of being important carriers. In this State we have evidence against the first three.

(3.) Birds.—Certain investigators, including the writer, have observed new cases of blight in pear trees, starting from fresh sap sucker wounds in the bark. As these trees were in some instances well isolated from other cases it seemed probable that the bird was

responsible.

(4.) Pruning tools, etc.—It has been demonstrated repeatedly that if we cut through an active case of blight and then cut through a healthy limb the latter may become infected. The percentage of such cuts that will result in new infections is much higher in summer than in winter.

(5.) Bloom.—Repeatedly we have seen hundreds of cases of blight in a single tree from blossom inoculations. Also we have seen trees that failed to bloom almost free while their neighbors that had blossomed showed many infections. Varieties that bloom early sometimes escape blossom infection, because the blossoms have fallen before the insects had had a chance to visit any of the bacterial exudate from the "hold-over" cases, which sometimes do not give forth this liquid until an unusually warm day.

(6.) Water sprouts or suckers.—These are very tender and more liable to attack than slow-growing twigs. When growing around the base of the tree or upon large limbs, they often bring about the death of the tree by giving the blight a start near a vital region.

(7.) Crown-gall.—It has been observed repeatedly that galls are readily attacked by blight, and trees thus attacked are badly damaged or entirely killed.

(8.) Susceptibility of the tree to inoculation.—It is a fact well known to plant pathologists that when we inoculate a tree by wounding the bark and inserting virulent blight bacilli, or by putting them inside freshly opened flowers, the disease will sometimes follow and sometimes not. Briefly, we may mention that some varieties are easier to inoculate successfully than others and that in a susceptible variety the disease is more readily produced in summer than in winter, in hot weather than in cold, in rapidly growing parts than in slowly growing, and in small limbs than in large ones.

Of the conditions that influence the severity of blight after the attack is made there are at least five.

(1.) Variety.—This is the most important of all these factors. Perhaps no varieties are entirely immune, but some are so nearly so that they never suffer more than a little twig blight under ordinary circumstances, while in others, like the Alexander and the Transcend-

ant crab, the disease runs into the large branches and trunks even when the other conditions mentioned below are quite against the progress of the disease.

- (2.) Soil fertility.
- (3.) Soil moisture.
- (4.) Temperature.

Anything that contributes to a rapid growth of wood makes the tree more susceptible, and a rich soil under a high state of cultivation and abundance of moisture and hot growing weather, all work to this end. Probably this explains to some extent the severity of the disease in the Bitter Root Valley. Dry, sod-bound, upland orchards often resist the blight so well that no attention is ever paid to it.

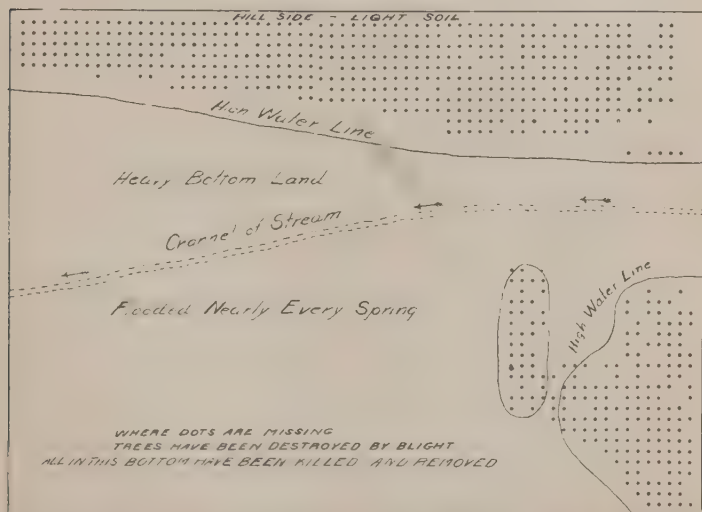


FIG. 7. Plot of a pear orchard, showing how the severe attack of blight on the heavy, wet, bottom-land has destroyed the trees there, while on the higher land, which was poorer and drier, the blight remained mostly in the smaller branches. The dots represent trees still living. All were reasonably healthy until blight struck the orchard two years before plot was made.

(5.) Age.—Young trees just coming into bearing seem to suffer most, while very old trees with slower growth and thicker and harder bark resist it much better.

These facts explain in a measure why the disease will in some trees die out in the small twigs without injuring large limbs, while in other trees it will run through the bark to the roots.

Control.—On the subject of control we have little to add to what was stated in circular 2 of this station, and this will, therefore, be repeated here with a few modifications, especially in the classification of varieties with reference to susceptibility.

In a single sentence we can say that the only method of curing a blighted tree is to cut out and burn all affected parts. This seems simple enough, but there are important details that determine between success and failure. As a matter of fact very few inexperienced men are successful, largely because they will not pay close enough attention to these important details. The following rules should, therefore, be thoroughly mastered and religiously followed:

(1.) See that no blight is allowed to winter over in the trees. The most effective time of the year to cut it out is late fall or early winter, though summer cutting is advised also.

(2.) In the dormant season the blighted branch should be cut off about a foot below any visible portion of the disease; in the summer two or three feet below. Even if this necessitates cutting off a larger limb it should be done. It is this rule that is transgressed most often and with the most serious consequences.

(3.) After each cut the saw or shears must be disinfected. The disinfectant can best be carried in a milk bottle attached to a belt, and can be applied with a swab. Small corrosive sublimate tablets (four to a pint of water) make an excellent disinfectant. A 5 per cent solution of carbolic acid is also good.

(4.) Burn all diseased parts promptly after cutting, especially in summer. It is a general belief that insects crawling over such material may reinfect the trees.

(5.) Inspect every tree carefully after the orchard has been gone over. Even an expert, when cutting out blight, has to do this two or three times to get every case, and a case or two left may

ruin the whole campaign by starting the blight in the blossoms the next season. A reinspection should always be made just before the buds open, as missed cases are often more easily found at that time. **Never omit this.**

(6.) Pruning. Orchards in infested districts should be kept free from water sprouts at the foot of the trees, and from suckers and fruit spurs on the main limbs; otherwise the bacteria, entering through these tender parts, will quickly reach the roots or the trunk.

(7.) Tillage and irrigation. Anything that favors a rapid, succulent growth of the tree makes it more susceptible to blight. It is, therefore, most important that blighted orchards should have no more tillage and water during the first half of the growing season than are absolutely necessary to the making of the crop. Barnyard manure should be applied only to the more resistant varieties.

(8.) Kill the green apple aphid. Observation and experience have convinced us that the winged adult of this insect is the most important carrier of the blight after the bees stop working in the flowers. Thorough spraying with tobacco extract for the green aphid should greatly reduce the spread of blight during the summer.

(9.) Do not plant the most susceptible varieties. Nothing is so essential in fighting this disease as to avoid planting susceptible varieties, which are almost certain to be killed if attacked, and to pull out or top-work those already growing. It would be impossible and quite useless to list here all known varieties of apples and pears and state the degree of susceptibility of each, for most of them have no commercial value in this State. The Montana fruit growers, however, may find here listed most of those varieties that have a commercial value in one or more of our important sections, and they should be guided by it in the setting of new orchards.

Class A.—Relatively resistant, i. e., the blight seldom runs far in limbs more than one-half inch in diameter, and usually makes only a twig blight.

Ben Davis

Rome (Beauty)

Gano

Stayman Winesap

Oldenburg (Duchess)

Class B.—Moderately resistant, i. e., the disease seldom runs far in limbs more than three-fourths inch in diameter, and frequently

makes only a twig blight.

Baldwin	Grimes (Golden)
Black Twig (Mammoth)	Hibernal
Delicious	Lawver (Delaware Red)
Fameuse (Snow)	McIntosh
Gravenstein	Northwestern Greening

Class C.—Moderately susceptible, i. e., the disease frequently penetrates the smaller limbs (an inch or less in diameter), but seldom the main limbs or the trunks, except in very rapidly growing trees.

Banana (Winter)	Wealthy
Esopus (Spitzenburg)	Wolf River
Jonathan	Yellow Transparent
McMahon	Hyslop Crab
Northern Spy	Martha Crab
Tompkins King	Whitney Crab
Wagener	

Class D.—Very susceptible, i. e., when infections appear in a tree; the blight extends rapidly into the larger limbs and trunks, and the tree is usually killed.

Alexander	Transcendant Crab
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In considering the above lists the grower should understand that classes A, B, and C rank fairly close together, and that any of those varieties can probably be grown successfully even in blight-infected districts of the State; while between class C and class D there is considerable difference, the latter being much more susceptible. It is an exceedingly important fact that in trees belonging to classes A and B the blight germs nearly always die out in the bark before winter and almost never live over until the next spring, while in those belonging to class C they frequently live over winter, and in those of class D they are very likely to do so and thus start a new infection in the orchards at blossoming time. Our orchardists should not attempt longer to grow these two varieties. When the State was free from blight some of them proved very profitable, but now they are doomed to be replaced by others that are more resistant. It would be most unwise, therefore, for a grower to set them out.

The claim is sometimes made by those who have grown fruit

in the East or Middle West previous to coming to Montana that the cutting out of blight from apple trees is not necessary, that such a practice was very little followed where they came from and yet apples were grown with very little trouble from blight. The explanation is simple. In those sections the most susceptible varieties, as the Alexander and Transcendant crab, either have been little planted or have since been killed out. As the blight germs usually die out during the winter in other varieties, there is much less danger of an outbreak. The few cases that appear usually make only a twig blight in orchards where sod is grown and irrigation is not practiced. Doubtless we will have such a condition here after the susceptible varieties have disappeared and orchardists cease to overstimulate the growth of their trees, but meanwhile we must make a hard fight to save the industry. It should be remembered, however, that nearly every apple district, East and West, has a severe outbreak now and then that requires severe cutting.

A very noticeable result of the blight campaign that has been carried on in this State is the almost complete elimination of the most susceptible varieties from the districts first infested and a very marked consequent abatement of the disease in other varieties, and a destructive scourge of it in many varieties along the frontier where the disease has recently spread and where the Alexander and Transcendant crab are in varying stages of destruction.

The question may arise whether or not the practice of removing the blighted bark from the trunks and roots of apple trees, as described for the pear on page 316, is not preferable to destroying the trees entirely. After considerable experience, we must say that we do not believe this method has any practical value in saving the apple trees of Montana when they become blighted in the trunk or below. This is explained by the following facts:

(1.) While our apple trees are valuable they are not worth nearly as much as are pear trees in certain valleys of California, Oregon, and Washington, and the long and tedious operation would not be justified.

(2.) Even though we removed all the blight from the crowns of Alexander and Transcendant trees the repeated blighting of the tops would keep them unprofitable.

(3.) The work of this kind in California is done largely in the winter time when the disease is not active, and the more rigorous climate of Montana makes winter work of this kind impossible.

(4.) In a large percentage of the cases in Alexanders and Transcendants the blight is not clearly enough defined to make such operations successful. When pear trees are dormant one can see quite clearly how far the blight has progressed, but in apple trees of the varieties named it is often impossible to say just where the disease stops. If such delicate operations were attempted many would be failures, because some infected bark was left.

(5.) Apple trees will not stand so well as pear trees the removal of large areas of bark from the crown. What would class as a fairly successful operation on a pear tree would practically ruin an apple tree.

It is evident that our orchardists must not make the mistake of assuming that a process that will sometimes succeed with the pear in some places will succeed commercially with the apple in Montana.

CROWN-GALL OF APPLE

Crown-gall, also known as root-gall, root-knot, crown-knot, and hairy-root, is one of the most common diseases of nursery stock and the subject of much controversy. It is characterized by the production of outgrowths or swellings most frequently located on the crown at the union of stock and cion, but sometimes on the roots and occasionally on the branches. It attacks all our common fruit trees and shrubs and many other plants besides.

Cause.—For years all efforts to determine the cause of crown-gall were unsuccessful. Its infectious nature was easily established but not until 1907 was it definitely proved that the exciting agent for these abnormal growths is a bacterial organism*. Later investigations by laboratory studies and cross inoculations with pure cultures from many different host plants have shown most conclusively that this organism is responsible for nearly all forms of crown-gall as we now know it on many different trees, shrubs, and herbaceous plants. There has long been a tendency for some nurserymen and fruit growers to regard the disease as a direct result of mechan-

* *Pseudomonas tumefaciens* Smith and Townsend

ical injury such as that brought about by grafting, budding, pruning, and careless cultivating. However, we now know that while wounds made in this way serve to let the specific organisms gain entrance through the outer protective covering, such injuries alone will not result in this disease. If there are those who still insist upon this belief it is because they are ignorant of the published facts, incompetent to judge of the conclusiveness of experimental data, or prefer the erroneous explanation to the true one.

At present comparatively little is known about the life habits of this bacterial organism in nature, though it has been the subject of considerable study when growing in pure cultures under laboratory conditions. That it thrives well in the tissues of many plants is obvious. There is much evidence that it lives well in some soils at least, as the percentage of galled trees in the seed bed has in some cases been shown to increase from year to year if the same soil is used continuously; and old raspberry patches from which galled plants were removed have been reported to communicate the disease to trees or bushes set there later. Some have even claimed that the organism must be found in virgin soil because apparently healthy plants or seeds set there produced galled stock. We must remember, however, that there are many chances for the soil to become slightly infected in planting and caring for the seeds or plants; indeed the organisms may have been on them and not observed as they cannot be detected even by the most careful inspection. From all the evidence it is safe to conclude that this organism is common on the roots of nursery stock, in the soil about galled trees and plants, and in land previously planted to diseased stock, but it is doubtful if it exists in most uncultivated soils.

Fortunately crown-gall is not highly contagious, and in the case of the apple at least it is doubtful if many new cases will develop as a result of tying up healthy stock in the same bundle with diseased trees, or from setting a healthy tree where a diseased one was removed. This statement, however, does not apply to some other fruits, as for example, peach, almond, grape, and raspberry.

Symptoms.—Crown-gall in advanced stages is easily recognized and so far as the apple is concerned it is not likely to be mistaken

for any other trouble, excepting, perhaps, the work of the woolly aphis. The mature galls are often one to two inches in diameter and occasionally much larger. Before the cause had been discovered certain pathologists classified the different manifestations of the disease, according to the symptoms produced, into crown-gall and hairy-root. Crown-gall was further subdivided into "hard" gall and "soft" gall. It is now well established that these are different types of the same disease, i. e., all are caused by the same organism. Just why it should behave differently in different cases has not been fully determined.

The typical galls are most often found on grafted stock at the union of stock and cion. They may protrude from one side or they may extend nearly or all the way around. More rarely they appear at wounds on the side or tip of any of the roots or even on seedlings where no wounds of visible size can be found. They may be whitish and so soft they may be easily scraped off with the finger nail, or a dark reddish brown and as hard as the normal wood; and there are all stages between. Sometimes they are nearly smooth, but more often they are warty and rough from irregular growth and many cracks.

In the typical hairy-root form, dense tufts of fine hair-like roots with few branches grow out rapidly nearly at right angles from the crown, the tap root, or occasionally from a lateral root. These are often light-colored at first and give the impression of being very succulent. Upon drying they seem to shrink a little more than healthy roots. With this form of the disease especially, there is often a failure to produce strong anchor roots. Sometimes these tufts of fibrous roots grow out from swellings or galls, producing what has been termed woolly knot. There is a tendency for sprouts to grow from such knots also. *

While the infection is usually confined to the underground portion of the trees, there are notable cases of an aerial form, especially on quince, apple, and grape. Some of these galls on trunks and branches grow to enormous size and persist for many years. They may be either ordinary galls or accompanied by tufts of hairy root and water sprouts.

While typical and well developed cases of this disease are easily

recognized, there are many others that are very perplexing to the nursery inspector. These fall mostly under five headings.

(1.) The trees may be shipped when the galls have just started and cannot be distinguished from the ordinary callus that forms at the union. When we remember that both gall and callus start at a wound, that both consist of masses of cells that have been produced with abnormal rapidity by an unusual stimulus, that the callus and many of the galls are of about the same color and con-



FIG. 8.. Crown-gall of apple, very common form.

sistency, at least in the beginning, and that both originate as a rule in the cambium region, we can well appreciate the difficulty. Indeed there are many instances in which no one, excepting by the most long and tedious laboratory studies, could say with certainty whether a tree is affected with the first stages of crown-gall or not.

(2.) An abnormally large and protruding callus has formed from an imperfect joining of stock and cion or, more frequently, from storing the grafts too long before planting. There are two serious objections to such a callus; the inspector may be unable to determine whether the trees are diseased or not and, as has been shown, such calluses of delicate structure with a large exposure unprotected by an outer covering are especially liable to become infected and later develop galls.

(3.) Other agencies than the crown-gall organism may cause an abnormal growth of slender roots in dense tufts almost identical in appearance with the hairy-root form of crown-gall. Of these agencies unfavorable conditions of moisture and temperature may be mentioned. It might seem that a statement of these conditions from the nurseryman to the inspector should suffice, but even granting the honesty of the nurseryman we must remember that some true hairy-root may have developed along with the tufts of roots that are being explained, and in such cases it would be practically impossible to separate the one from the other.

(4.) When nursery trees have an unusually good root-system, fine roots are sometimes produced with such luxuriance that the inexperienced have suspected the hairy-root form of crown-gall. Accusations have been made by nurserymen that inspectors have been guilty of this mistake, but whether or not these accusations were made in good faith we cannot say. Instances of inspectors making this mistake have not come under our observation, though we have seen fruit growers, new at the business, who were unable to make the distinction.

(5.) The inspector's work is sometimes complicated by the removal of galls and tufts of roots before shipment. In this State we have sometimes had to deal with this condition. The difficulty is made even greater by puddling the roots with thin mud to cover the scars. We class this procedure with dishonesty and must regard

with suspicion all puddled stock, and scars on the crown and main roots.

As to the responsibility for these five difficulties, the second, third, and fifth rest largely with the nurseryman and are more or less under his control.

Host plants.—No other bacterial organism is known to attack so many different species of plants as that causing crown-gall. Dozens of different kinds have been proved by pure culture inoculation to be susceptible and there is every reason to believe that the list could be increased to hundreds if experimental work were carried far enough. Those that have proved susceptible include species in widely separated plant-families. The disease is found most commonly in nature among the trees and shrubs of the family Rosaceae, including apple, pear, quince, peach, almond, plum, apricot, cherry, raspberry, blackberry, and rose, as well as the grape, poplar, willow, hop, Paris daisy, and sugar beet, belonging to other families.

By the agencies that operate in field, garden, and orchard it is quite readily transmitted to the peach, almond, raspberry, and sugar beet, but less easily to the apple and pear. In the nursery, however, it readily attacks the apple and pear also. In some parts of Europe it is regarded as a menace to sugar beets, but it has not as yet become a serious factor in the beet industry of this country.

Damage.—Owing to the different behavior of this disease on various crops and even on different kinds of fruit trees, it would be very misleading to apply a general discussion of the destructiveness of crown-gall to all fruits. It is quite apparent from the literature on this subject that there has been too great a tendency to apply the results of investigations of this disease on one kind of fruit in one locality to other kinds of fruit in a different locality. In a general way we may note that the apple is more likely to outgrow the disease than the peach, almond, and raspberry. We will, therefore, confine the remainder of this discussion to the apple and treat of the damage done to other fruit in later pages of this circular.

There exists among the various classes of people interested in this disease the widest difference of opinion as to its destructiveness. Some hold on the one hand that it is one of the worst apple diseases,

while others believe that the trees outgrow it and suffer no permanent injury. Most plant pathologists take an intermediate position. This lack of harmony seems to have come from drawing general conclusions from a few observations, often imperfect, and from assuming that the disease behaves upon the apple the same as it does upon the peach and almond. No complete discussion of the ultimate effects of crown-gall upon the apple under a wide range of conditions has yet been published, but from the various notes on the subject and from our own observations in this and other states we draw the following conclusions.

Apple trees affected with crown-gall and planted in the orchard may meet with any of the following fates:

First, they may be killed outright by the gall in a short time.

Second, they may keep up a slow growth for years, making stunted trees smaller and shorter-lived than their neighbors, the galls slowly enlarging for years.

Third, they may make a fairly satisfactory growth and become profitable bearers and their slight inferiority can be detected only by a close comparison with healthy trees under the same conditions. Such a comparison being impossible, the orchardist usually thinks they are all right or, if he is not quite satisfied, he lays the trouble to the soil, climate, location, care, or some other condition. In such cases the galls disappear after a few years.

Fourth, the gall may pave the way for the entrance of wood-destroying fungi or for the blight bacillus. In such cases the gall usually does not get the blame it deserves.

As to which of these fates is the most common to crown-galled apple trees planted in Montana we can not say with certainty. Various members of the station staff, including the writer, have observed stunted trees of bearing age among larger ones and upon digging about the roots discovered large galls. Members of the State board of horticulture, inspectors, and prominent fruit growers have occasionally made similar observations.

In the spring of 1910 we set in one block one hundred and twenty galled trees and the same number of healthy ones of the same age and varieties. In the fall of 1912 the galled trees were found to average a little smaller than the healthy ones and one-half of each



FIG. 9. Crown-gall of apple, lower end of tap root destroyed.

kind was removed for examination. It was found that practically none of the galls had dropped off and that most of them had grown much larger. What is still more important, the root system of the galled trees was in nearly every case much inferior to the average of the healthy trees, and the trees were removed for examination with much less effort. The other half was left for examination at a more advanced age.

Summing up everything we are led to believe that most of such trees planted in this State would come in the third group,

i. e., with those slightly inferior to what they would have been had the disease not attacked them. Some, however, would doubtless fall in the second group, making distinctly stunted trees.

Besides the damage done in the orchard, we cannot overlook the fact that hundreds of thousands of nursery trees are destroyed annually on account of this disease, some at the nursery and others at the point of inspection. People are more and more coming to see that such trees had better be destroyed than planted.

Conditions affecting the disease.—It is evident from what has been written that there are some very important factors governing the fate of galled trees set in the orchard. We have not full data concerning these factors, but several have been mentioned.

(1.) Location of the galls.—One of the principal effects is to interfere with the circulation at the point where the gall is attached. It therefore follows in theory, and observation has confirmed, that a gall is most serious if located upon the crown, especially if it extends entirely around, girdling the tree. On large roots it would be somewhat less injurious and on smaller ones still less so. On the cut ends of small roots little damage would be expected. There is little evidence at present that new galls would ever appear on the crown or large roots from those so distantly located.

(2.) Size.—The important consideration here is the size of the attachment, for a large gall with a small neck is more likely to drop off than a broad flat one.

(3.) Type of the disease.—It is not safe to generalize as to the relative severity of the gall and the hairy-root forms. The first summer after setting the trees the hairy-root form seems to do less damage; indeed, there are instances of a better stand from such trees than from healthy ones, especially in a dry soil, due no doubt to the rapid absorption of moisture through these abnormal roots while the tree is becoming established. The later inferiority of such trees seems largely due to their frequent failure to produce strong anchor and feeding roots.

(4.) Number of galls.—Frequently there is but one gall on a tree, but where there are more the injury would be correspondingly greater, size and position being similar.

(5.) Complications.—In many cases a tree might recover or

at least continue to live, but for the interference of some other disease-producing organism whose entrance has been made possible by the gall. Of these complications wood rot and blight have been mentioned. We are informed on good authority that in certain parts of the Northwest a great many trees are destroyed by blight following gall, so many as to make gall an important factor in combating blight.

(6.) Variety.—Our data on this subject are limited but there are enough to indicate its importance. Of the varieties grown commercially in the State, the Wealthy and Oldenburg are reported as taking the disease readily in the nursery, while the Ben Davis, York Imperial, and Spitzenburg have more often succumbed after planting. We cannot assert, however, that there are not other varieties that are just as bad or worse.

(7.) Soil conditions.—There is some evidence that the galls persist longer and injure the tree more in heavy, wet soils than in light, dry ones, but our data are too meager to warrant conclusions.

(8.) Geographical location.—This cannot be regarded as a condition but a combination of conditions. It is worthy of note, however, that the reports would indicate more permanent injury to apple trees in the Rocky Mountain region and on the Pacific slope than in the middle and eastern states.

It is highly important that Montana orchardists who have set crown-gall trees in the past should inform this department of the Experiment Station of the fact so that more full and exact studies may be made.

Control.—In most cases crown-gall is incurable with our present knowledge. The trees may either free themselves from the disease or succumb to it, but there is little we can do to assist them. If the galls are located on side roots they may be removed with the pruning knife, and if the cut is made a couple of inches from the gall the infection will probably be removed, though a new infection may start at the wound made by the cutting. Many attempts have been made to save the trees by cutting off galls close to the crown. In some cases the wounds thus made were disinfected with copper sulphate, Bordeaux mixture, lime-sulphur, sulphur, or other materials, but new galls have appeared about the wounds in such

a large percentage of cases that we cannot regard this procedure as a success. This is quite to be expected for recent laboratory studies have shown that some of the bacteria are located in the root itself at the attachment of the gall, where they cannot readily be removed without much labor and a serious weakening of the root.

At present we have two general methods of combating the disease.

First, keep the percentage of diseased trees in the nursery as low as possible. It is doubtful if any large nursery can prevent crown-gall from appearing on its stock, but the number of cases can be held down somewhat. The following recommendations are made by Dr. Geo. G. Hedgecock,* who has made an extensive study of crown-gall under nursery and orchard conditions.

"No method of entirely eliminating the disease in the nursery has been discovered. The per cent of healthy trees can be greatly increased by carrying out the following suggestions: 1. Select roots and scions for root-grafting, or seedlings and buds for budding from healthy plants. 2. Carefully fit the scions to the root in root-grafting and wrap tightly and firmly the cut surfaces in the union, especially the lower end of the scion. 3. Avoid the long storage of root-grafts, unless in cold storage, since the overproduction of callus favors the entrance of the disease. 4. Avoid wounding trees in the nursery row with the hoe or cultivators. 5. Avoid planting in wet, heavy soils."

Second, refuse absolutely to plant galled trees in the orchard. Any one who will knowingly plant such trees in this State shows a lack of information or a lack of business judgment that does not speak well for his success as an orchardist. It is urged by some that to destroy all affected stock tends to keep up the price; but how much? Certainly not more than five cents per tree, and how much of a consideration is this compared with the whole cost of producing a bearing tree? Comparing the galled tree with the healthy we find that the freight is the same, the cost of planting is the same, the cost of cultivation is the same, the cost of pruning is nearly the same, and the interest on the investment in tree, labor, and land is nearly the same. Even granting that none of the trees

* National Nurseryman, Vol. XIX, 1910.

will be killed outright or very badly stunted, which is not likely to be the case, we find that when they come into bearing the galled trees are at least a little inferior to the healthy ones. At this stage we would gladly pay the initial difference of five cents several times over to have a perfect tree. A difference in yield of only five pounds of apples would more than pay this initial difference in cost in a single year.

It is impossible for each grower to protect himself against the introduction of such stock for he not only lacks the time and often the experience to sort it properly, but he cannot afford to enter into the necessary controversy with the nurseryman. It, therefore, behooves him to give every possible support to effective inspection laws and the authorities who enforce them. They can protect him much more perfectly and economically than he can himself. It has been stated that no reputable nursery now sends out galled stock, but such stock is sent to Montana every year in considerable abundance. Furthermore, the greatest incentive to the nurserymen to take the proper precautions to produce healthy stock and to destroy in the nursery that which is galled is the fear of its being rejected. If the inspection were relaxed we could reasonably expect a great increase in crown-galled stock.

APPLE SCAB

Scab is one of the worst diseases to which the apple is subject. It is safe to say that more spraying is done in the United States for this disease than for any other, but notwithstanding this the annual loss is still enormous, due largely to the fact that while our best and most successful orchardists use the spray pump freely, there are a great many others who do not. This disease does its chief damage by spotting the fruit, but often there is much injury to the leaves also.

Geographical distribution.—Apple scab may be found over the greater portion of the United States and in other apple-growing countries as well. In general it is most severe where the climate is cool and moist, and it is, therefore, more prevalent in the northern than in the southern states. A few sections, notably large portions of Colorado, Utah, Arizona, and New Mexico, where the weather is hot and dry, are nearly or quite free from it. There are also a

few valleys in other parts of the country where the apple industry is new and the disease has not yet found its way.

In Montana the disease is relatively new. About 1900 it appeared on Flathead Lake and by 1907 a few cases could be found as far north as Columbia Falls. Now it has spread to Libby and Troy. About 1904 it was found at Thompson and by 1911 had spread east to Plains and Paradise. In 1908 it was found in a few orchards between Bonner and Missoula, having probably started in one of them in 1907. By the autumn of 1908 a few cases had reached Lolo. In 1909 it spread to Stevensville, in 1910 to Corvallis, and in 1911 practically to the upper end of the Bitter Root Valley. East of the Continental Divide it has been reported from two localities, one near Townsend and the other near Park City. It is probable that these represent three or four separate introductions into the State.

Cause.—Apple scab is produced by a fungus* that has a parasitic stage on the fruit, leaves, and sometimes the twigs, and a saprophytic stage on the dead leaves. These stages were once supposed to represent two distinct fungi and a different name** was applied to the fungus on the living leaves and fruit.

The winter spores from the dead leaves are distributed in late spring and early summer and some of them attack the leaves of the unfolding buds, the flower stalks, the calyx, and a little later the young fruit. Here spots are formed of a dark, greenish, mold-like growth on which the summer spores are borne in great numbers on the tips of slender mycelial branches. They are greenish-brown in color, one-celled, oval in shape, microscopic and easily carried by the wind. (Figs. 2 and 4.) Those that fall on young leaves and fruit under favorable conditions germinate (fig. 11) and start new infections. In autumn the leaves fall to the ground and the fungus growing on them continues to develop during the winter and spring. With the opening of spring the winter spores are formed inside of delicate transparent sacs called asci, each containing eight spores. These sacs are enclosed in black protective bodies called perithecia. The perithecia are barely visible to the naked eye, pear-shaped,

**Venturia inaequalis* (Cooke) Winter.

** *Fusicladium dentriticum* (Wallr.) Fuckel.

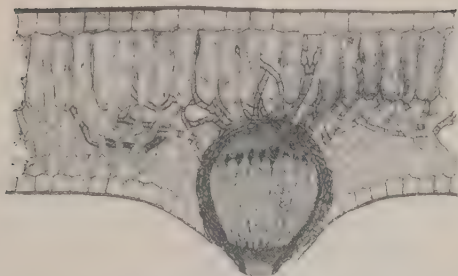


FIG. 10. Section through a dead leaf, showing perithecium of scab fungus containing asci and ascospores. (Highly magnified. Semi-diagrammatic.)

attached at the larger end, with a tiny hole in the small end for the escape of the spores. These spores are greenish-brown in color and composed of two cells. Each perithecium contains numerous asci and consequently hundreds of winter spores (ascospores). As each diseased leaf under favorable conditions may bear a large number of perithecia, the total number of winter spores formed in an orchard is astonishing. These are responsible, in a large measure at least, for the new infection each spring. On fallen fruit out of

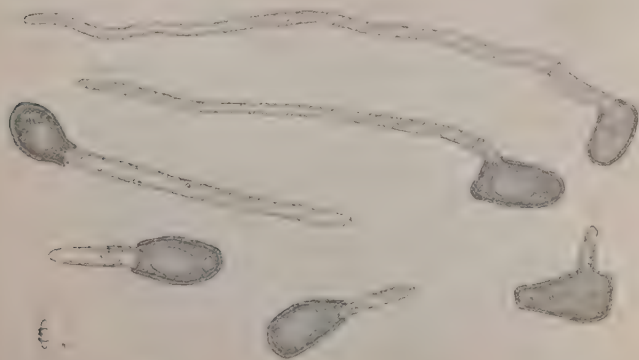


FIG. 11. Germinating summer spores of apple scab. (Magnified 730 times.)

doors the winter-spore stage seldom, if ever, develops, although on fruit protected in cellars summer spores capable of germinating have been found as late as April and it is likely that some may survive still longer. It is believed that the summer spores on the leaves and fruit and those that have been distributed by the wind do not survive the winter and play no part in the next season's infection. There is evidence that the spots on the twigs may carry the disease over winter to some extent although we do not believe that they are of much importance in Montana as compared with the fallen leaves.

Symptoms.—On the leaves the scab fungus forms olive green mold-like patches, roundish in shape and about one-eighth to one-half inch in diameter, except where several run together to make a large irregular patch. These spots are at first pale and difficult to see but later become a very dark, dull green. Often the leaf bulges upward at the spot with a corresponding depression on the under side. If the leaves are attacked when the buds are unfolding, the under side is most often infected as this is the first to be exposed; but later in the season the spots appear in greater abundance on the upper side. The leaf stalk is sometimes attacked. In severe cases the leaves are so badly injured that they drop, leaving the tree more or less defoliated.

On the fruit the spots appear as tiny specks which grow larger

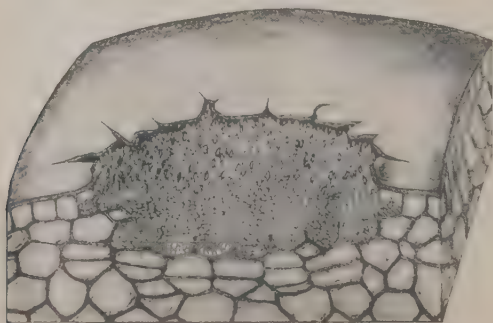


FIG. 12. Section through small scab spot on apple fruit, showing formation of summer spores. (Highly magnified. Semi-diagrammatic.)

and burst open, revealing a dark green or nearly black interior with a ragged, white, papery margin which is the torn cuticle of the apple. The individual spots are usually one-fourth to one-half inch in diameter, but may grow into each other to make larger scabby areas. They are dry and do not penetrate more than one thirty-second of an inch into the fruit. A dwarfing of the growing fruit often takes place at the disease spot, causing a distorted apple which may crack open. Not infrequently it falls prematurely.

The fruit may be attacked at any stage of development, but the most common time is when it first forms. In some seasons spots may even be found on the flower stalks and on the calyx and the green basal portion that later becomes the fruit. About two or three weeks after blossoming time the infections become less frequent and in most seasons they are rare after the fruit is half grown. Early fall infections, however, do occur if the weather is cool and damp, especially on the more susceptible varieties as the McIntosh, Fameuse, and White Winter Pearmain. Even after the apples of these varieties are picked and stored they may develop scab if there are spores on the surface or not all the spotted ones have been sorted out, providing sufficient moisture is present.

On the twigs scab spots may frequently be found, especially on the McIntosh. During the seven years the writer has been making observations on scab in Montana, twig infections have been found four different seasons, 1908, 1911, 1912, and 1913*. These spots practically always appear on shoots of the present season's growth, but the scars may remain for two or three years. Usually they are so small as to be scarcely visible and therefore easily overlooked, but sometimes they reach a size of one-eighth inch in diameter. They are irregularly oblong in shape, being a little longer up and down the shoot than sidewise. They form blisters of a yellowish-gray or light-brown color and burst open in a ragged fashion, revealing a greenish-black interior. Under a hand lens they show some resemblance to the spots on the fruit. They are most often in small groups.

* As scab does not appear in the vicinity of Bozeman, I have not had opportunity every year to make a thorough search for cases on the twigs. I feel quite confident, however, that some could be found on unsprayed McIntosh nearly every year.

but sometimes the whole shoot is nearly covered with spots.

The tree as a whole is not perceptibly impaired in general vigor unless from the effects of defoliation.

Host plants.—Practically speaking, the apple is the only host for this fungus, though there are one or two reports of it on related plants. A closely related fungus causes a scab on the pear (see page 318), but the two are botanically different and each is confined to its own host plant. Flemish Beauty pears in scab-infested apple orchards in different parts of the State have been entirely free. A disease with symptoms similar to scab is found on service berry, but it also is distinct.

Damage.—The annual loss from scab over the United States is very great, due to the following reasons:

(1.) The disease is found almost everywhere the apple is grown and appears in most places every year in more or less abundance.

(2.) Many growers neglect their orchards and do not attempt to prevent the disease.

(3.) Many who make some attempt to control it perform the work imperfectly, or take a chance now and then on the attacks being so light as to make spraying unnecessary.

(4.) Even when using the best methods, a little scab will appear, especially on very susceptible varieties or in a very wet season.

(5.) Whatever expense is incurred for preventing scab must be charged up to this disease.

As illustrative of the loss from scab in Montana, we would state that at a conservative estimate the loss due to scab in the Bitter Root Valley in 1912 was 15 per cent of the entire crop. Some individual orchards ran as high as 95 per cent, while others were practically free from the disease. Data are not yet available for the loss in 1913.

Conditions affecting apple scab.—It is a noticeable fact that the severity of scab varies greatly. Some of the conditions that determine this are well known.

(1.) Prevalence of the fungus. With the first appearance of scab in a new territory the number of cases is usually small for a year or two, but in a long-infested territory there are usually plenty

of spores everywhere to make certain a heavy infection if other conditions are favorable. A few cases have been cited, however, where the destruction of the leaves in somewhat isolated orchards before the winter spores were distributed has resulted in practical freedom from scab for a season, even when no spraying was done.

(2.) Moisture is an exceedingly important factor, as the spores cannot germinate and, therefore, cannot attack the leaves and fruit if they remain dry. Frequent light rains with continuous cloudy weather, especially about blossoming time, are almost sure to result in a severe infection. Even heavy dews are sufficient to insure considerable infection in damp bottom lands where evaporation is slow. In the same orchard we have often noticed a distinct difference in the severity of scab in low lands and damp pockets and on benches where air currents keep the fruit and foliage drier.

(3.) Temperature is a factor as shown by the greater prevalence of the disease in the northern states than in the southern. This has much to do with late summer and fall infections which are much more likely to occur in cool than in hot weather. Doubtless the more frequent rains that accompany a cool summer are a factor here also.

(4.) Varieties of apple show great difference in their susceptibility to scab. In an average year if the trees are unsprayed one variety may have 90 per cent of the fruit affected and another in the same orchard not more than 5 per cent. If well sprayed this may be reduced to practical freedom in one variety, while another will still have 5 to 15 per cent. The following table is based on actual observations in western Montana.

TABLE SHOWING SUSCEPTIBILITY OF VARIETIES TO APPLE SCAB*

Class 1	Class 2	Class 3	Class 4
Practically resistant	Moderately resistant	Moderately susceptible	Susceptible
Hubbardston	Alexander	Akin	Black Twig (Mammoth)
Oldenburg (Duchess)	Baldwin	Arkansas Black	Blue Pearmain
Wagner	Gano	Ben Davis	Early Harvest
Wealthy	Gravenstein	Delicious	Fameuse (Snow)
York Imperial	Grimes (Golden)	Esopus (Spitzenburg)	Lawver (Delaware Red)
	Livland Raspberry	Jonathan	McIntosh
	Minkler	Maiden Blush	Peck
	Northwestern Greening	Monmouth	Red June
	Ortley	Northern Spy	Shiawasee
	Tetofsky	Pewaukee	White Pearmain
	Tompkins King	Red Astrachan	
	Yellow Transparent	Red Canada	
		Rhode Island (Greening)	
		Rome (Beauty)	
		Walbridge	
		Wolf River	
		Yellow Bellflower	

The above list was prepared by Mr. H. E. Morris of this station for a bulletin soon to be published. It contains only those varieties which are of more or less commercial importance as grown in the State.

There are two agencies chiefly responsible for the spread of scab,—mankind and winds. The carrying of the disease through a distance of many miles is chiefly done by man through the shipping of nursery stock with twig infections. The scab spots are so inconspicuous that it is very easy to overlook them in rapid nursery-stock inspection. It is possible also to introduce the disease by the shipping of scabby fruit. Early apples, as the Yellow Transparent, may be shipped in and the scabby ones, or scabby portions of parings, thrown out; and the spores escaping from these may cause enough late summer leaf infections the same season to establish the disease in that locality. There is a possibility, too, that scabby apples stored until late in the spring and then shipped to another locality may start a spring infection in the same way. In view, however, of the fact that nearly all the apple-growing sections of the country are already infested, the cases that would start in this way would be few compared with those from fallen leaves in the vicinity. These methods of introduction are of little importance, excepting to a few localities where the disease is still unknown.

The spread through short distances is brought about largely by winds. Through distances up to a mile or more the spores appear to be blown in considerable abundance, and a few are evidently carried for several miles. If the reader will refer to page 202 of this circular and note the rate of spread up the Bitter Root Valley he will get an excellent idea of the possibilities of wind distribution of scab spores. He should keep in mind in this connection that between Bonner and Darby there are a number of places where a stretch of several miles would have to be taken at one step, i. e., there would be no chance for the spores to alight in an orchard and cause a new center of infection from which the disease could spread further the same season.

Control.—On the subject of scab control much has been done and many papers have been written. "

Spraying is, beyond everything else, the most important means of prevention. Spraying should be done to all varieties every season. Experience has proved that it is a poor business proposition to take a chance on scab being light during any year. It is necessary to have all parts of the leaves and fruit coated with a fungicide at

all times when infection could take place. The infection possibilities being different in different varieties and seasons, only approximate rules can be laid down.

We doubt the advisability of using a dormant spray for scab alone, when neither oyster-shell scale nor blister-mite is present, although it is sometimes recommended. Very susceptible varieties (class 4, page 308) should have regularly at least four sprayings; the first just before the flower buds open, i. e., when the trees are "in the pink", the second when about three-fourths of the flower petals have fallen, the third two weeks after the second and the fourth two weeks after the third. In a cool rainy August these varieties will require a fifth spraying late in that month to prevent a fall infection. If a heavy rain follows any application within a few days, the grower should spray again as soon as possible. Moderately susceptible varieties (class 3) will usually require the first three applications, and a fourth if the weather is cool and damp and there are some scab spots on the leaves. Moderately resistant varieties (class 2) should be given the first two applications at least. The most resistant varieties (class 1) will usually be nearly scab-free if sprayed once, when the petals are falling.

When oyster-shell scale is present, it will be necessary to spray with lime-sulphur just before the leaf buds open, but this must not take the place of the "pink" spray for the more susceptible apples in classes 3 and 4.

For a fungicide to spray with the orchardist may choose between two,—Bordeaux mixture and lime-sulphur. Some have controlled scab better with the one and others with the other. On the whole we believe that Bordeaux mixture is considerably more effective against scab, but on certain varieties, especially in a humid atmosphere, there is some danger of its russetting the fruit. Lime-sulphur is now used mostly in this State, but we believe that for many varieties Bordeaux is preferable in most parts of the State. Perhaps

Description of colored plate. 1, McIntosh apple with scab spots; 2, fruit cut open to show depth of penetration; 3, leaf with many young spots; 4, leaf with older spots; 5, twig with many spots, winter condition; 6, spots on twig, slightly magnified.



APPLE SCAB

a combination of the two, using for the first two sprayings described above lime-sulphur and Bordeaux mixture for earlier and later sprayings will give the best satisfaction on some varieties, especially those moderately resistant to Bordeaux injury. We recommend that the Bordeaux mixture be used in the 4-4-50 strength and the lime-sulphur about 1.5° Baume or 1.01 Sp. Gr. For fuller information concerning the preparation of these fungicides, dilution tables for the lime-sulphur, and the danger of Bordeaux injury to different varieties see circular 36 of this station.

When it is necessary to spray McIntosh or other varieties after the fruit is nearly mature, the deposit left by either Bordeaux or lime-sulphur is objectionable and may necessitate wiping the fruit. To avoid this difficulty we would suggest a careful trial of ammoniacal copper carbonate for this late spraying. It is entirely untried for this State and should be used on a small scale only until it has proved successful.

As to why so many sprayings are required there are several reasons. There is usually more or less rain to wash off the fungicide; some kinds lose their strength by exposure to the atmosphere; the fruits grow in size and cause myriad cracks in the coating through which the fungus may attack; and new leaves are formed which must be protected.

In addition to spraying there are other methods that aid in the control of scab. By properly pruning the trees the air currents and sun can dry the dew and raindrops more quickly and the center of the tree is more easily sprayed. The more susceptible varieties should be grown on the higher lands in so far as their soil requirements will permit. Raking and burning the leaves is sometimes advocated. This seems impracticable under our conditions at least, but something can be accomplished by plowing them under. What most needs to be emphasized is that scab control be given a prominent place in orchard management and not kept subordinate to other farming operations.

BALDWIN SPOT

The disease known as Baldwin spot has also been described under several other names, including dry rot, brown spot, fruit pit and bitter pit. Fruit pit would best describe it, but it has been known

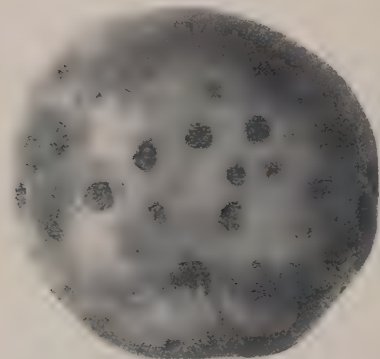


FIG. 13. Baldwin spot on Yellow Newtown apple.

longer and more generally under the name Baldwin spot.

It is rather widely distributed over the United States and other apple-growing countries. The disease appears about picking time, sometimes a little before, but more often after the fruit is in storage. There may be seen at first round spots about one-eighth inch in diameter, slightly sunken and of a normal color. They may easily be overlooked at this time. They are dry and do not penetrate far into the fruit at this early stage. In a few weeks they become more deeply sunken, turn brown in color, and some of them enlarge to one-fourth inch in diameter. If the fruit is cut at this time, it will be seen that the flesh under the spots is brown and rather dry. Often dry, brown streaks follow an irregular course inward for one-half to three-fourths of an inch and later they may run practically to the core. In addition there may be isolated brown spots in the flesh some distance from the surface. The discolored flesh may have a normal taste or be somewhat bitter.

The cause of Baldwin spot is unknown. It is not believed to be a parasitic organism. One explanation that has been offered is that it is caused by a faulty circulation of water through the fruit.

While this disease is called Baldwin spot it is by no means confined to the Baldwin variety. Many others are more or less subject to it, the Northern Spy being most often complained of in this State.

During the last few years confusion has arisen between the Baldwin spot and a fruit spot of fungous origin, studied in New

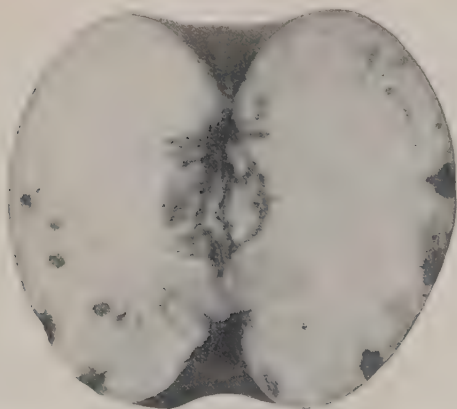


FIG. 14. Baldwin spot, showing brown spots in the flesh. Same apple as shown in figure 13.

Hampshire by Brooks. This fruit spot has not been reported in Montana, but to distinguish it from the Baldwin spot we submit the following in comparison.

(1.) The fruit spot appears about the middle of August and the Baldwin spot about picking time.

(2.) The fruit spot is often accompanied by a reddish tint, or by a deeper color on a red fruit, while the Baldwin spot is at first a normal color on the surface. Later both turn a dark brown.

(3.) The fruit spot is scarcely sunken at all when it is first visible and only slightly so when fully developed, while the Baldwin spot is distinctly sunken almost from the start and the depression is one-sixteenth to one-twelfth of an inch deep when fully developed.

(4.) The flesh under the fruit spot is discolored for only a small fraction of an inch in depth, while under the Baldwin spot it is discolored for one-fourth to one inch or more.

(5.) The fruit spot is caused by a fungus* while the Baldwin spot appears not to be caused by a fungus.

No method is known for controlling Baldwin spot, but it is suggested that apples of a variety that shows a tendency to the disease be marketed early.

* *Phoma pomi* Passer, formerly called *Cylindrosporium pomi* Brooks.

JONATHAN SPOT

This disease affects the Jonathan variety especially, but Esopus (Spitzenburg), Yellow Newtown, and a few other varieties are sometimes attacked. It appears late, usually while the apples are in storage. The spots are dark brown or nearly black, distinctly sunken, and resemble externally those of the Baldwin spot. They are very superficial, however, scarcely extending into the flesh at all, and in this way they may be distinguished from those of the Baldwin spot. The disease is of frequent occurrence and often causes heavy loss. The quality of the fruit is scarcely impaired, except in appearance, but this is such as to spoil the salability of otherwise high-grade fruit.

The cause is unknown, but like the Baldwin spot it seems not to be due to a parasite, but to some physiological condition. Spraying has given no benefit and the only recommendation for preventing it is to get the apples in cold storage as soon as possible after picking and dispose of them early. This will apply to fruit from trees whose previous crops have suffered from Jonathan spot.

PEAR BLIGHT

The blight of pear is caused by the same organism as the blight of apple. Much, therefore, that was said about the disease under apple blight applies to the pear and need not be repeated here.

In general the pear is more susceptible to blight than the apple; that is, the disease when it gains entrance runs through the bark more rapidly. There is, however, nearly as much varietal difference in the pear as in the apple and the more resistant varieties of pear do not blight as badly as the more susceptible varieties of apple.

The losses from pear blight have been enormous all through the United States and other countries; indeed the pear suffers more from this disease than from all others combined. Whole orchards have been exterminated by it in many different states. In California, for example, it destroyed nearly 125,000 trees in a single county in two years.

The symptoms in the pear are much like those in the apple, except that the affected leaves turn much darker, indeed nearly black, and the bark turns darker also and is more easily distinguished from the healthy.

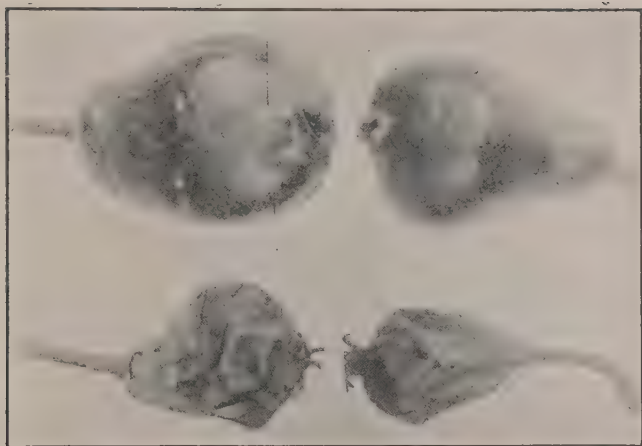


FIG. 15. Young pear fruits. The two shriveled ones were inoculated with the blight bacillus, the other two uninoculated.

As already noted there is much difference in varieties of pear with reference to the blight, but none are by any means immune and trees of all varieties have been known to blight to the ground under favorable conditions. Below is a partial list arranged approximately in their order of susceptibility.

- | | |
|------------------------|-------------------|
| 1. Clapp Favorite | 8. Clairgeau |
| 2. Idaho | 9. Anjou |
| 3. Angouleme (Duchess) | 10. Seckel |
| 4. Comice | 11. Le Conte |
| 5. Howell | 12. Winter Nellis |
| 6. Bartlett | 13. Kieffer |
| 7. Flemish Beauty | |

It should be understood that this order of susceptibility varies somewhat in different sections. The reports are especially conflicting for the Angouleme, Seckel, and Le Conte. Only a few of these varieties have been grown in Montana as yet, but the list will serve as a general guide to susceptibility. Of these varieties the first two may be considered somewhat worse than any varieties of apple, and the next five are about like the most susceptible class of

apples (class D, page 288), the eighth and ninth are about like class C of apples and the remainder compare fairly well with class B.

The same conditions that make apple trees susceptible to blight affect pears in a similar way. In the case of soil moisture, however, the effect may be even more striking, for pear trees will thrive in much wetter land than apples. I have seen large pear orchards up to twenty years or more of age growing behind levees of a river in soil practically saturated to the surface and in bottom-lands inundated by water for one to three months of the year. These orchards were thrifty and very profitable until attacked by blight when they were badly injured and some of them entirely destroyed, while orchards on adjacent benches, or in some cases a portion of the same orchard that extended up on a hillside, were only moderately injured.

The questions may frequently arise, can pears be grown successfully in Montana, notwithstanding the blight, and will the growing of pears menace the apple industry? It is doubtful if the first three or four varieties in the above list can be grown with commercial success, and we would not advise the growing of any variety, except by those who will make a study of this disease and devote considerable time each year to the control of blight. Any who will give blight this attention should be able to control it in such varieties as Anjou and probably in the Bartlett and Flemish Beauty.

It must be remembered in comparing varieties of pear like the Flemish Beauty and Bartlett with those of apple like the Alexander and Transcendant crab, that are about equally susceptible to blight, that we find the disease much more easily controlled in the pear, as the lighter color of the healthy bark, the darker color of the diseased bark, and the sharper line between the two, make the cases much more easy to find during the dormant season. By diligent search we can find practically every case in pear trees, but in these varieties of apple some cases are almost invisible and are sure to be overlooked and give trouble the next year.

If taken care of pear trees cannot justly be regarded as dangerous to surrounding apple orchards, but if neglected they are very likely to become hotbeds of infection.

On the Pacific coast where pear trees grow with unusual vigor

and give returns much greater than in most other parts of the United States, considerable labor is sometimes expended to save large and valuable trees that have become infected in the trunks or even the roots. The diseased bark is removed and the wound is disinfected, and when dry painted to protect the wood from rotting. If the crown is nearly or quite girdled, bridge grafting is practiced, that is, one end of a shoot is inserted below the wound and the other end above. If enough such shoots are inserted on different sides of the tree its life may, with good luck, be prolonged for some time, though such a tree is necessarily inferior to a normal one and shorter-lived. I have done much work of this kind in California, but doubt if the value of pear trees in Montana is great enough to warrant it, and do not consider it a success with susceptible varieties of apple anywhere. The reasons for this are given on page 289. Furthermore, only an expert or an unusually careful and patient orchardist with much practice and an abundance of time at his disposal can succeed in this method of saving pear trees. It is at best a long and tedious process and we have seen many failures.

For any who intend planting pear orchards we would advise specially prepared trees. As the Chinese sand pear ("Japanese" stock) is more resistant to blight than the French stock and does not sprout so badly, roots of this variety should be used. Upon these Kieffer cions should be grafted and the trees so prepared should be set deeply enough to insure roots being sent out above the union. After these trees have been set in the orchard about two years they may be top-worked about one foot from the trunk to Anjou or any other desired variety. Such trees will blight in the tops as badly as any, but if the disease should run down a limb to the union with the resistant Kieffer it will usually stop and the tree can be saved. Such trees may be made up to order at any reliable nursery at but slight increase in cost, the only additional trouble being the top-working in the orchard. Such trees have been grown on a commercial scale and the system is well past the experimental stage.

CROWN-GALL OF PEAR

What has already been said of apple crown-gall (page 290) applies, so far as our knowledge goes, to the same disease in the pear. It seems safe to say that when galled trees are planted in

the orchard the extent of injury in the case of the pear is intermediate between the apple and the peach. It must not be forgotten, however, that crown-gall often paves the way for an attack of pear blight and that blight in the crown is worse than in any other portion of the tree.

PEAR SCAB

This disease forms spots on the pear very much like those of apple scab. The similarity is so close indeed that many have supposed the two diseases to be identical. Pear scab is found almost everywhere the pear is grown. In Montana no cases were reported until within the last three years and even now it is restricted to a few orchards in the Bitter Root Valley and in the extreme western end of the State.

Cause.—Pear scab is caused by a fungus* very similar to the one causing apple scab. The microscope reveals but slight differences between the two so that even some plant pathologists have had doubts as to whether or not these differences are of importance. In this State, however, we have found conclusive proof that the two diseases are not identical. The apple scab appeared in this State at three widely separated points,—Flathead Lake, Thompson, and Bonner, probably representing the introduction of as many separate strains of the apple scab fungus from outside the State; but in all three localities Flemish Beauty pear trees in the infested apple orchards remained free from scab for several years until the pear scab fungus was introduced and most of them are still free.

The life history of the pear-scab fungus is almost identical with that of the apple-scab fungus already described, but the winter spore stage has not been found so abundantly.

Symptoms.—Olive green spots appear on the young fruits, often making them distorted and sometimes causing them to crack open. Often the fungus ceases to develop after a few weeks and the continued growth of the fruit changes the spot to a corky brown color almost lacking in the original green and with a rough russeted surface. The leaves are more or less spotted, also depending much on variety and location. The spots on the twigs are much like those of apple scab, but more abundant as a rule, and there is strong reason

* *Venturia pirina* Aderhold.

to believe that these twig spots are largely responsible for the new spring infections.

Pears show much varietal difference in susceptibility to scab though none are entirely immune. The Flemish Beauty is particularly susceptible, the Winter Nellis, Seckel and Anjou are moderately susceptible, the Bartlett is moderately resistant and the Kieffer is somewhat more so. All varieties will be affected more in damp localities and in a wet season.

The infection period seems to be under most conditions rather short,—a week before and a week or two after the blossoms open. In most sections there is no late infection in an average year.

Control.—Spray with Bordeaux mixture as soon as the leaf buds are well started to open, again just before the flower buds open, and a third time when the petals have nearly all fallen.

Lime-sulphur seems unlikely to take the place of Bordeaux mixture as a preventive for pear scab, at least for the sprayings before the flowers open. The disease is so new in Montana that we do not know how difficult it will be to combat it here, but some unsprayed Flemish Beauty trees have borne practically 100 per cent of scabby fruit.

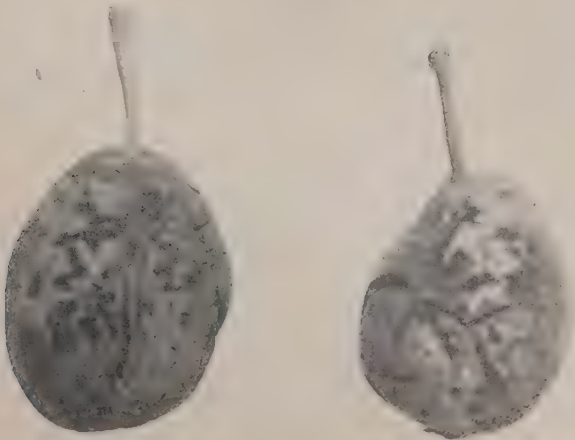


FIG. 16. Flemish Beauty pears affected with pear scab.



FIG. 17. Section of peach leaf affected with leaf curl. Asci containing ascospores are forming on upper surface; a, cuticle of leaf; b, bits of mycelium of fungus; c, young asci with spores not yet formed; d, spores just formed; e, spores being divided into smaller ones; f, spores discharging; g, empty ascus.

PEACH LEAF CURL

The peach industry in this State is necessarily limited to a few sections, but where the peach has been grown leaf curl has so far been the disease of most importance.

Geographical distribution.—In practically every country where the peach is grown, this disease is prevalent. In the United States its distribution is almost universal, but it is the most severe on the Pacific slope, in the Great Lake region and in other sections where the climate is cool and damp, and of small importance in the drier portions of Colorado, Utah, Nevada, Arizona, New Mexico, and Texas.

In Montana it is often severe around Flathead Lake.

Cause.—Botanists have known for half a century that peach leaf curl is caused directly by the attack of a fungus*, but the success of this fungus in attacking its host is so dependent upon damp weather that many orchardists have adopted the idea that the weather is directly and solely responsible. The fungus attacks the leaves principally, but to some extent the twigs and fruit. In the leaves the mycelium grows between the cells from which it absorbs nourishment, and on the upper surface it forms innumerable sacs or asci in which the spores are formed. At first there are eight in each, but often these divide at once to form a larger number. The asci are borne naked on the leaf without any protective covering and the spores are discharged almost as soon as formed, mostly in the month of June in this State. After forming this enormous crop of spores the mycelium shows no further tendency to reproduce and soon dies.

In the twigs the fungus forms a perennial mycelium that lives on year after year. It was once supposed that this extended into the young leaves in the spring by growing through the leaf stalks, but it now seems clear that this takes place only to a very slight extent.

There is much evidence that the spores though thin walled, apparently delicate, and unprotected by any natural covering, have sufficient vitality to live over winter and that they are chiefly responsible for the spring infection.

It is a curious fact that the spores when first formed show little tendency to attack healthy leaves, and late summer infections are rare. It is not until the following spring, nearly a year after the spores are discharged, that a definite infection period occurs.

Symptoms.—The leaves are attacked very early in the process of bud expansion. There is reason to believe that many infections take place when the leaves are still scarcely visible between the brown bud scales.

The leaves at this stage unfold rapidly, but soon it may be seen that some of them, the infected ones, are not behaving normally.

* *Exoascus deformans* (Berk.) Fuckel.

The fungus may invade a small portion of the leaf tissue or the entire leaf. The affected portion grows more rapidly than the healthy, causing it to pucker and curl. If the whole leaf is involved it looks as though the midrib and veins had shrunk lengthwise or failed to elongate in proportion to the regions between. The infected portion also becomes thickened and of a dryish, leathery texture. In color it is for the most part a lighter green, often whitish, but in places it has a tinge of red and not infrequently an indefinite patch of brilliant crimson.

The diseased leaves persist for a few weeks, performing their functions in a feeble manner, and then drop. If many are thus involved the tree is nearly defoliated and the after effects are serious. The fruit is likely to drop after the defoliation, new buds sometimes start in an effort to replace the lost foliage, the trees fail to mature properly, and are not in condition to withstand a severe winter.

The young twigs are frequently attacked also and become somewhat swollen and distorted. In these twigs the mycelium remains



FIG. 18. Peach leaves distorted by leaf curl.

alive over winter, and it was once supposed that this was responsible for most of the leaf infection the next spring, but it has since been found that it plays but a minor part.

Damage.—Before a remedy for leaf curl was found it ranked among the worst of orchard diseases. In 1893 the estimated loss for the United States was \$3,000,000 or more. Since then the treatment now in use has been perfected and quite extensively put into practice, and by it the annual loss has been greatly reduced, especially in commercial orchards; but still there are so many who fail to spray regularly that the total loss for the country is very considerable.

Conditions affecting the disease.—Of these there are but two that need mention,—weather and variety. Cool, rainy weather at the time the buds are opening is the most important. Indeed such weather favors the disease so much that many have supposed it to be the direct cause. Such weather regularly occurs in some parts of the country and here leaf curl is always severe. In other sections such weather comes at irregular intervals, and following it the disease is bad, while other localities with comparatively dry weather during April and May are practically free from it.

Varieties differ considerably in their susceptibility. The Elberta is notably susceptible; but as there are so few varieties that can be grown successfully in Montana it need only be said that the Triumph, the one mostly planted here, is rather susceptible as is also the Early Crawford. Fortunately the disease can be easily controlled on any variety.

Control.—In no disease are the results of a single spraying more striking than in this one. Whereas at one time it was feared that the peach industry was doomed, and recommendations were made to cut out affected branches and even affected trees, now anyone can protect his orchard with small expense.

One spraying only is required. In different parts of the country this has been given with success during all the months from December to April. We recommend spraying from a month to two weeks before the buds open. The greatest danger is from waiting too long. Spraying after the buds begin to unfold seems to give little benefit.

Both Bordeaux mixture and lime-sulphur are good fungicides for this disease. Where San Jose scale is prevalent, lime-sulphur is mostly used. Here in Montana Bordeaux mixture 5-5-50 is preferred but lime-sulphur testing 26° to 33° Baume, diluted 1 to 15, may be used if more convenient. The strength of the solution may be varied considerably. If the spray is applied thoroughly and not too late, almost perfect control may be expected.

CROWN-GALL OF PEACH

Crown-gall of the peach is caused by the same organism as that of the apple. As crown-gall in general was fully discussed under diseases of the apple (page 290) we need here add only such special manifestations as are peculiar to the peach.

Crown-gall seems much more easily communicated to the peach under ordinary orchard conditions than to the apple. Setting trees in ground previously mixed with minced galls has shown this quite conclusively. It is further reported to have been transmitted to seedlings set close around older galled trees and to nursery stock set where badly infested raspberry bushes had been removed. Whether or not it spreads from tree to tree in the orchard as a rule has not been established, but it certainly seems inadvisable to set a young healthy tree where a galled one has been removed, at least without waiting two or three years.

When attacked the peach is as a rule injured much more than the apple. Numerous reports indicate that a large per cent of such trees will be badly stunted. Many die without ever coming into profitable bearing. Peach stock with any trace of gall must be regarded as worse than worthless to set in the orchard.

GOOSEBERRY MILDEW

The worst disease to which the gooseberry is subject is mildew. It is caused by a fungus* which attacks the leaves, young stems, and fruits. It has been known to attack the currant also, but we have not seen such cases in this State.

The mycelium spreads over the surface, but does not penetrate the host plant except to send suckers (haustoria) into the epidermal cells for nourishment. The mildew is first visible in early summer

* *Sphaerotheca mors-uvae* (Schw.) Berk. and Curt.



FIG. 19. Gooseberry mildew on stem and leaves.

in the form of white patches of a moldy appearance, which soon turn a dull brown as the summer spores are formed. These spores are borne in chains on the ends of mycelial branches. Late in the season resting spores are formed in sacs or asci, enclosed in spherical black bodies (perithecia) which serve to protect them. These ascospores live over winter and infect the plants the next spring. The leaves and tips of the stems are somewhat distorted in bad cases, but the principal injury is to the fruit, which is made unsightly by the brown patches and may even crack open.

The disease is especially severe on many of the finer English varieties. It is prevalent almost all over the United States and has



FIG. 20. Gooseberry mildew on fruits.

been introduced into Europe where it has done great damage.

Control.—Gooseberry mildew can be controlled at relatively small expense. The bushes should be sprayed just as the buds are opening with Bordeaux mixture, lime-sulphur (summer strength), or liver of sulphur (one ounce to two gallons of water). This should be followed with liver of sulphur at intervals of ten days until seven or eight applications have been made. The more susceptible varieties may require spraying every week for ten weeks.

Some growers have found benefit from a spraying of lime-sulphur (dormant strength) just before the leaf buds open in addition to the summer treatment. So much spraying may seem discouraging to those who have not been used to spraying bush fruits; but they must remember that many bushes can be sprayed in an hour, that the cost of materials per bush is very small, and that a small spraying outfit is sufficient for the purpose. Many in this State who are now neglecting their bushes could spray them with profit.

CROWN-GALL OF RASPBERRY AND BLACKBERRY

Crown-gall has been discussed rather fully under diseases of the apple (page 290) and briefly under the diseases of peach and pear. In all these plants it is caused by the same bacterial organism.

It is a very serious disease in the raspberry and blackberry. Whereas the apple and pear, partly by virtue of their size, may out-

grow the galls to some extent, this does not hold true for the bush fruits under consideration. Often the galls enlarge out of all proportion to the canes. Furthermore, the disease is more contagious in these fruits than in the apple, they being in this respect more like the peach. This, combined with the fact that raspberries and blackberries are set much closer than these fruits, would lead us to expect a spread from plant to plant through the patch. Actual field observations seem to confirm this belief. It is, therefore, especially important to have the inspection of these stocks most rigid and to plant them on ground free from the crown-gall organism.

STRAWBERRY LEAF SPOT*

The leaf spot, or leaf blight as it is sometimes called, is probably the most common disease of the strawberry. It is found on both wild and cultivated forms, but in Montana it is not very common on cultivated plants. In a few cases, however, we have found it doing such serious damage as to show its dangerous possibilities here.

The disease attacks principally the leaves, forming at first small red spots. These enlarge to about one-fourth inch in diameter and take on the appearance so characteristic of the disease. The mature spots have a grayish-white center with a conspicuous border of deep red or purple. Summer spores are quite regularly formed in the dead tissues of the whitened centers, and late in the summer resting spores may also be formed in asci contained in perithecia partly imbedded in the leaf. Sometimes the stems of the fruits are attacked also, which is quite disastrous.

Control.—It is probable that spraying for strawberry leaf spot will not be necessary in this State excepting on very susceptible varieties, or during seasons that are hot in June with frequent showers. We have seen severe cases of it controlled in several instances by a single spraying of Bordeaux mixture applied just before the first blossoms opened; **but a second application as soon as the fruit is picked is recommended.** In severe cases the beds should be mowed and burned over as soon as dry to kill the fungus in the diseased leaves. This can be done without serious injury to the plants.

* Caused by *Mycosphaerella fragariae* (Tul.) Lindau.



FIG. 21. Strawberry leaf spot.

HORTICULTURAL LAWS AND INSPECTION

It is not the purpose of this section to take up in comparison the horticultural laws of the different states or even to discuss fully the laws of our own State. Copies of the Montana law may be had by applying to the State horticulturist or to any member of the State board of horticulture. It is our intention to briefly discuss the purposes of horticultural laws and the benefits to be derived if such laws are properly constructed and rightly executed.

The purposes of such laws are chiefly two,—to prevent the introduction of diseases and insect pests into the State and espec-